SHM Paper Questions
Jan 2002—Jan 2010 (old spec)

1 To celebrate the Millennium in the year 2000, a footbridge was constructed across the River Thames in London. After the bridge was opened to the public it was discovered that the structure could easily be set into oscillation when large numbers of pedestrians were walking across it.

Q1 Jun 2002

(a) What name is given to this kind of physical phenomenon, when caused by a periodic driving force?

....

(1 mark)

(b) Under what condition would this phenomenon become particularly hazardous? Explain your answer.

....

....

....

....

....

....

(4 marks)

(c) Suggest **two** measures which engineers might adopt in order to reduce the size of the oscillations of a bridge.

measure 1 ....

....

measure 2 ....

....

(2 marks)

Q2 Jan 2002

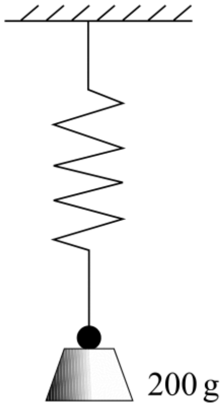


Figure 1

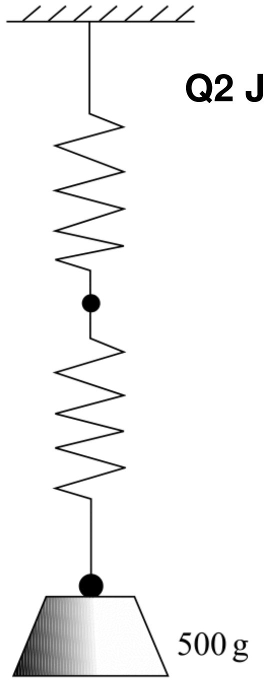


Figure 2

(a) When a 200 g mass is suspended from a spring, as in **Figure 1**, it produces an extension of 3.5 cm. Calculate the spring constant, *k*, for this spring.

....

....

(2 marks)

(b) A spring identical to that in part (a) is joined to the lower end of the original one and a 500 g mass is suspended from the combination, as shown in **Figure 2.**

(i) State the value of the new spring constant for this combination of two springs.

....

(ii) When the 500 g mass is displaced it performs small vertical oscillations. Calculate the number of oscillations made in one minute.

....

....

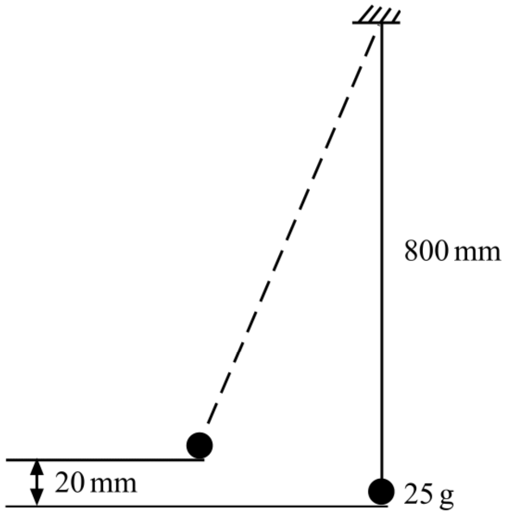
....

....

(3 marks)

1 A simple pendulum consists of a 25 g mass tied to the end of a light string 800 mm long. The mass is drawn to one side until it is 20 mm above its rest position, as shown in the diagram. When released it swings with simple harmonic motion.

Q1 Jan 2003



(a) Calculate the period of the pendulum.

....

....

(2 marks)

(b) Show that the initial amplitude of the oscillations is approximately 0.18 m, and that the maximum speed of the mass during the first oscillation is about 0.63 m s^{-1}.

....

....

....

....

....

....

....

(4 marks)

(c) Calculate the magnitude of the tension in the string when the mass passes through the lowest point of the first swing.

....

....

....

....

....

(2 marks)

1 (a) A body is moving with simple harmonic motion. State **two** conditions that must be satisfied concerning the *acceleration* of the body.

Q1 Jan 2005

condition 1 ....

....

condition 2 ....

....

(2 marks)

(b) A mass is suspended from a vertical spring and the system is allowed to come to rest. When the mass is now pulled down a distance of 76 mm and released, the time taken for 25 oscillations is 23 s.

Calculate

(i) the frequency of the oscillations,

....

....

(ii) the maximum acceleration of the mass,

....

....

(iii) the displacement of the mass from its rest position 0.60 s after being released. State the direction of this displacement.

....

....

....

....

(6 marks)

(c)

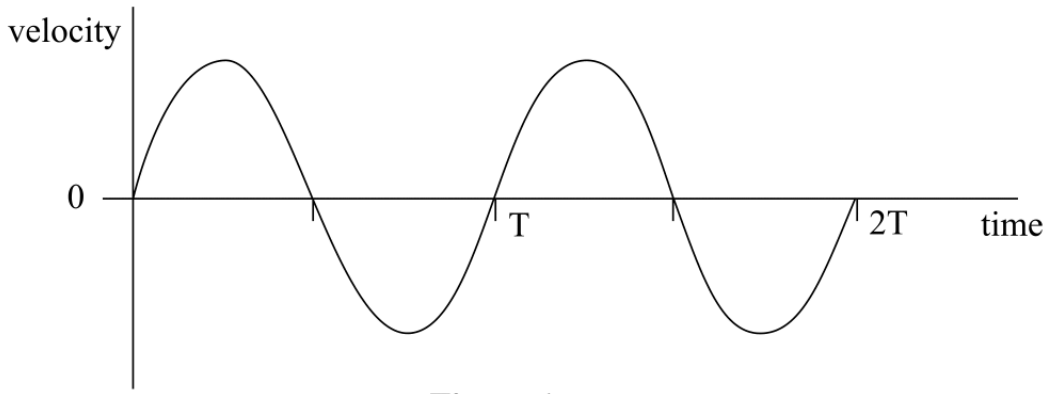


Figure 1

Figure 1 shows qualitatively how the velocity of the mass varies with time over the first two cycles after release.

(i) Using the axes in **Figure 2**, sketch a graph to show qualitatively how the displacement of the mass varies with time during the same time interval.

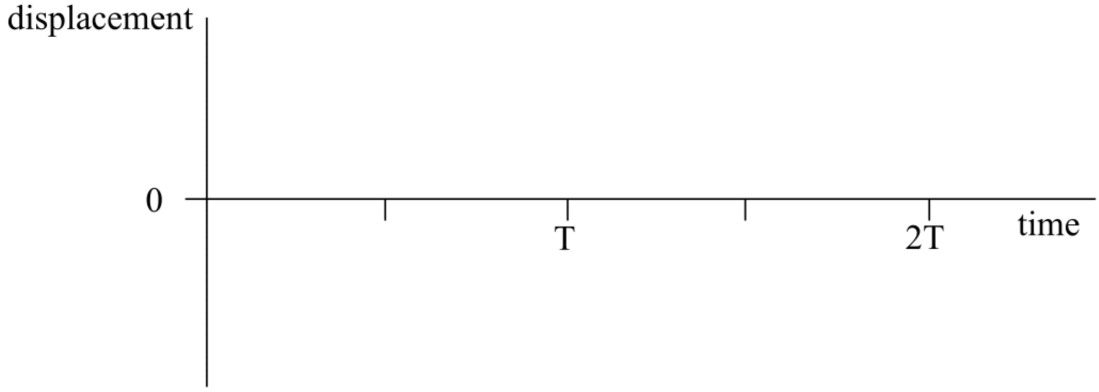
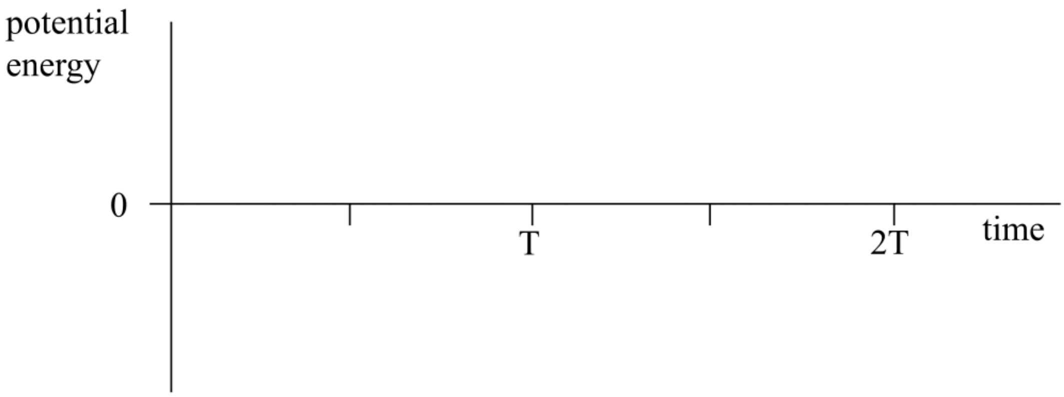


Figure 2

(ii) Using the axes in **Figure 3**, sketch a graph to show qualitatively how the potential energy of the mass-spring system varies with time during the same time interval.



(4 marks)

Figure 3

Describe what the observer would see as **Q** is rotated slowly through 360 °.

You may be awarded marks for the quality of written communication provided in your answer.

....

....

....

....

....

....

(2 marks)

---

1 (a) A spring, which hangs from a fixed support, extends by 40 mm when a mass of 0.25 kg is suspended from it.

Q1 Jan 2006

(i) Calculate the spring constant of the spring.

....

....

(ii) An additional mass of 0.44 kg is then placed on the spring and the system is set into vertical oscillation. Show that the oscillation frequency is 1.5 Hz.

....

....

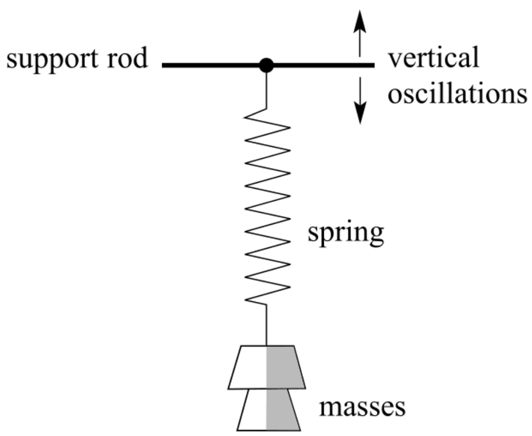
....

....

(4 marks)

(b) With both masses still in place, the spring is now suspended from a horizontal support rod that can be made to oscillate vertically, as shown in **Figure 1**, with amplitude 30 mm at several different frequencies.

Figure 1



Describe fully, with reference to amplitude, frequency and phase, the motion of the masses suspended from the spring in each of the following cases.

(i) The support rod oscillates at a frequency of 0.2 Hz.

....

....

....

....

....

(ii) The support rod oscillates at a frequency of 1.5 Hz.

....

....

....

....

....

(iii) The support rod oscillates at a frequency of 10 Hz.

....

....

....

....

....

(6 marks)

1 (a) Explain why, when a body is moving in simple harmonic motion, an equation of the form $a = -kx$ must be satisfied. In this equation, k is a positive constant and a and x have their usual meanings.

Q1 Jan 2009

....

....

....

....

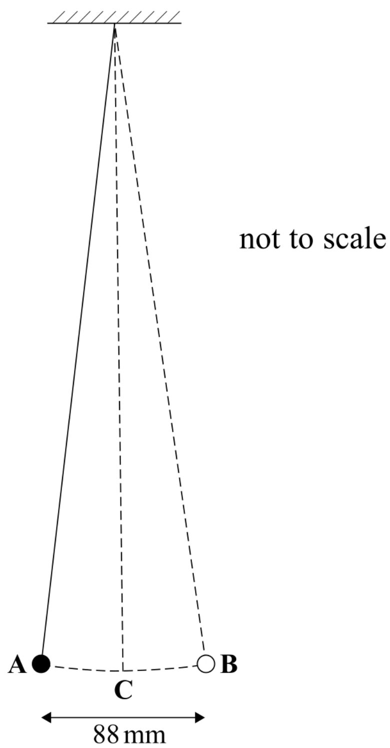
....

....

(2 marks)

1 (b) The length of a simple pendulum, from the point of support to the centre of mass of the bob, is 0.64 m. The mass of the bob is 1.5×10^{-2} kg. The pendulum is set into small amplitude oscillations. The distance from one extreme position of the oscillations, **A**, to the other extreme position, **B**, is 88 mm, as shown in **Figure 1**.

Figure 1



1 (b) (i) As the bob oscillates it passes through the equilibrium position **C**. Calculate the time taken for the bob to travel from **A** to **C**.

....

....

....

1 (b) (ii) Determine the maximum kinetic energy of the pendulum bob.

....

....

....

....

....

....

....

....

....

....

(7 marks)

1

Figure 1

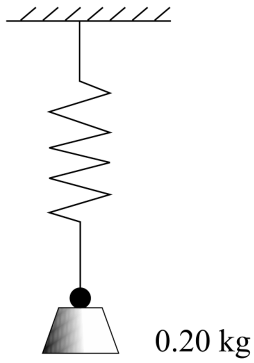
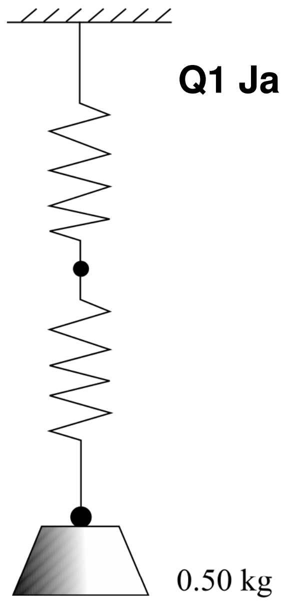


Figure 2



Q1 Jan 2010

1 (a) When a 0.20 kg mass is suspended from a spring, as in **Figure 1**, it produces an extension of 43 mm. Calculate the spring constant, k, for this spring.

....

....

(2 marks)

1 (b) A spring identical to that in part (a) is joined to the lower end of the original one and a 0.50 kg mass is suspended from the combination, as shown in **Figure 2**.

1 (b) (i) State the value of the new spring constant for this combination of two springs.

....

1 (b) (ii) When the 0.50 kg mass is displaced it performs small vertical oscillations. Calculate the number of oscillations made in one minute.

....

....

....

....

(3 marks)

This question is a little beyond the new specification in places and touched on some Y12 work

1

Q1 Jun 2005

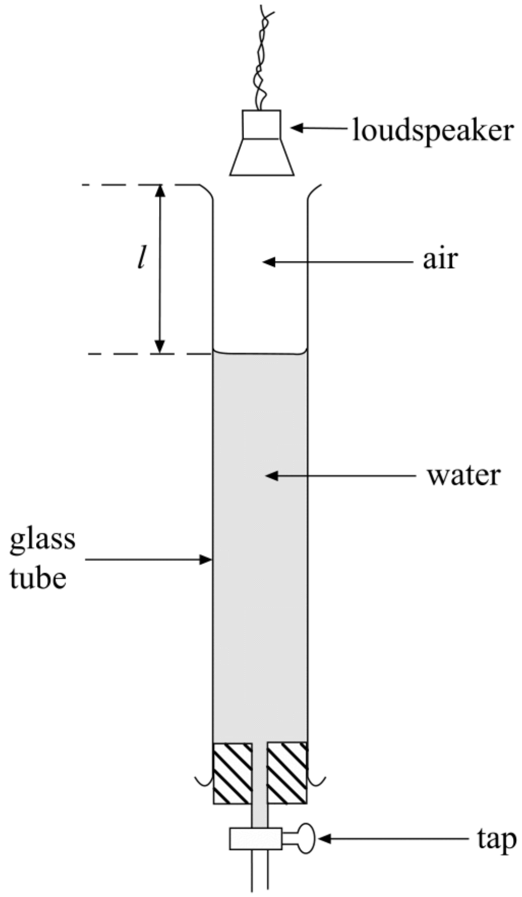


Figure 1

A small loudspeaker emitting sound of constant frequency is positioned a short distance above a long glass tube containing water. When water is allowed to run slowly out of the tube, the intensity of the sound heard increases whenever the length l (shown in **Figure 1**) takes certain values.

(a) Explain these observations by reference to the physical principles involved.

You may be awarded marks for the quality of written communication in your answer.

....

....

....

....

....

....

....

....

....

(4 marks)

(b) With the loudspeaker emitting sound of frequency 480 Hz, the effect described in part (a) is noticed first when $l = 168$ mm. It next occurs when $l = 523$ mm.

Use both values of l to calculate

(i) the wavelength of the sound waves in the air column,

....

....

(ii) the speed of these sound waves.

....

....

(4 marks)

1 (a) Give an equation for the frequency, f, of the oscillations of a simple pendulum in terms of its length, l, and the acceleration due to gravity, g.

Q1 Jun 2006

....

....

State the condition under which this equation applies.

....

....

(2 marks)

(b) The bob of a simple pendulum, of mass 1.2×10^{-2} kg, swings with an amplitude of 51 mm. It takes 46.5 s to complete 25 oscillations. Calculate

(i) the length of the pendulum,

....

....

....

....

....

(ii) the magnitude of the restoring force that acts on the bob when at its maximum displacement.

....

....

....

....

....

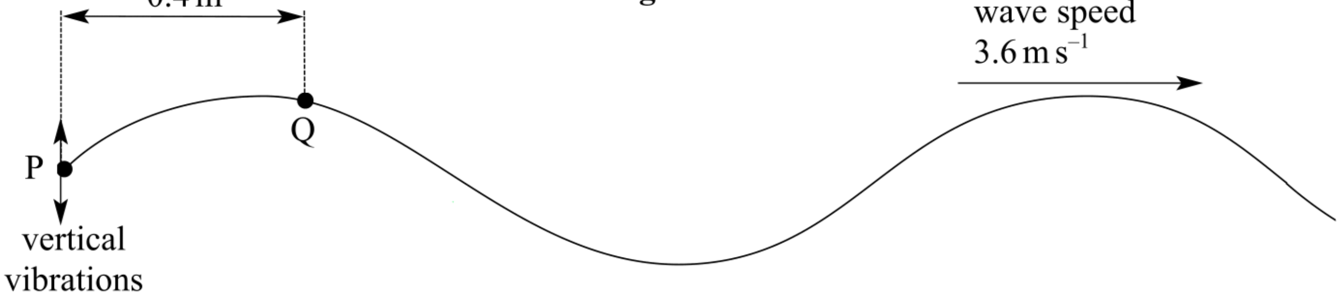
(6 marks)

This question is a little beyond the new specification in places and touched on some Y12 work

2 Progressive waves are generated on a rope by vibrating vertically the end, P, in simple harmonic motion of amplitude 90 mm, as shown in **Figure 1**. The wavelength of the waves is 1.2 m and they travel along the rope at a speed of $3.6\,m\,s^{-1}$. Assume that the wave motion is not damped.

Q2 Jun 2006

Figure 1



(a) Point Q is 0.4 m along the rope from P. Describe the motion of Q in as much detail as you can and state how it differs from the motion of P. Where possible, give quantitative values in your answer.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

....

....

....

....

....

....

....

....

(5 marks)

(b) Calculate the maximum speed of point P.

....

....

....

....

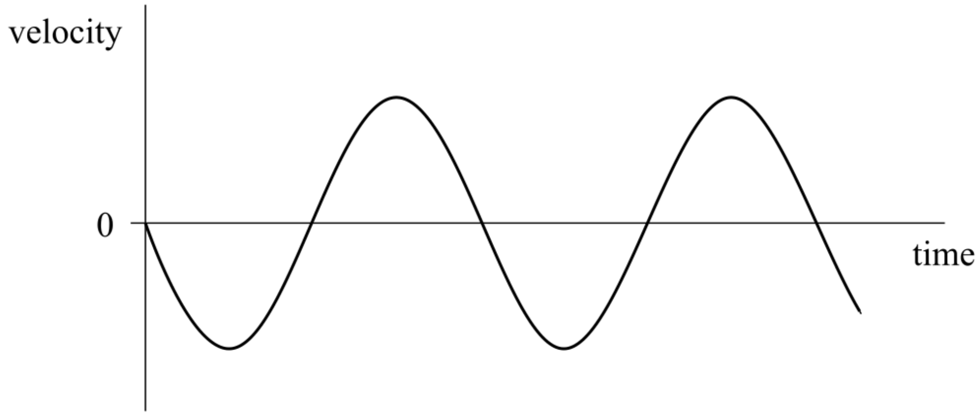
....

(3 marks)

1

Figure 1

Q1 Jun 2007



(a) A graph of velocity against time for a body moving with simple harmonic motion is shown in **Figure 1**.

(i) On **Figure 1**, mark with letter P a point at which the displacement of the body from its equilibrium position is zero, and mark with letter Q a point at which the displacement has its maximum positive value.

(ii) On **Figure 1**, mark with letter R a point where the magnitude of the acceleration of the body has its greatest value. Explain how this can be deduced from **Figure 1**.

....

....

....

(4 marks)

(b) The spring constant of a helical spring is $28\,\mathrm{N\,m^{-1}}$. A 0.40 kg mass is suspended from the spring and set into simple harmonic motion of amplitude 60 mm.

Calculate

(i) the static extension produced by the 0.40 kg mass,

....

....

(ii) the maximum potential energy stored in the spring during the first oscillation.

....

....

....

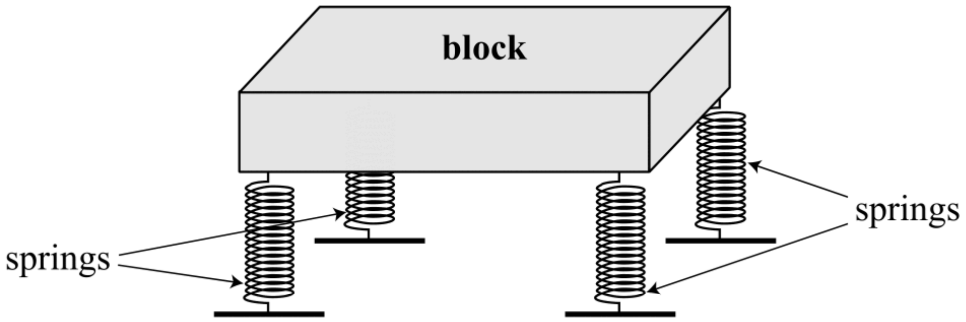
....

(4 marks)

1 A simple model for the suspension system of a car represents the car as a rectangular block, the weight of which is supported equally by four identical springs that are fixed rigidly at their lower ends, as shown in **Figure 1**.

Q1 Jun 2008

Figure 1



1 (a) The mass of the block is 1600 kg, and tests have shown that vertical oscillations of the block have a frequency of 0.92 Hz. Calculate the spring constant of one of the springs.

....

....

....

(2 marks)

1 (b) In a further test of the model, the whole block is displaced vertically downwards with an initial displacement of 90 mm. The block is then released at time $t = 0$.
You may assume that subsequently the block oscillates vertically with undamped simple harmonic motion.

Calculate, for a time 0.20 s later,

1 (b) (i) the vertical displacement of the block from its equilibrium position,

....

....

....

1 (b) (ii) the vertical speed of the block.

....

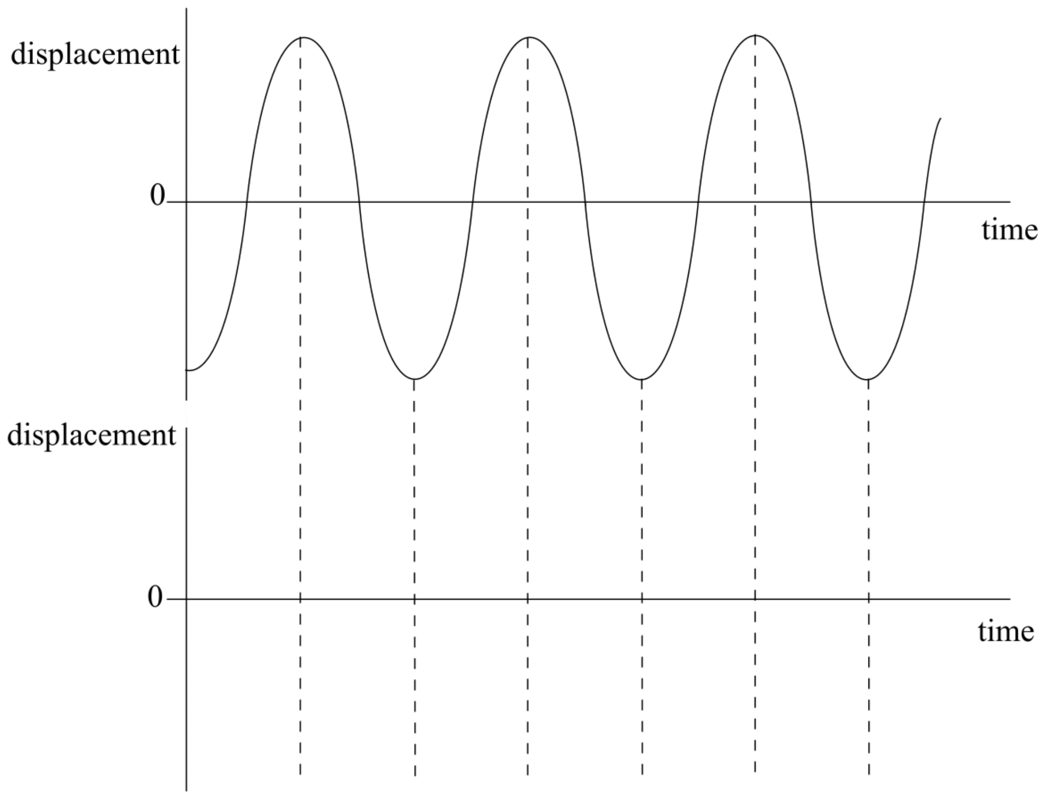
....

....

(4 marks)

1 (c) In practice, the vertical oscillations of a car are greatly reduced by fitting dampers (known as shock absorbers) to the suspension system. **Figure 2** shows how a graph of displacement against time would appear if there were no damping. Draw a graph on the axes beneath it to show how the oscillations would vary with time for a car fitted with light damping. You should use the same time scale.

Figure 2



(2 marks)

1 (d) An experiment is carried out to investigate the rattling of internal components of a car at certain engine speeds. When a loudspeaker connected to an ac source of variable frequency is placed in front of the rear-view mirror, violent vibrations of the mirror are produced when the frequency of the sound waves is 55 Hz.

1 (d) (i) Give the name of this phenomenon.

....

1 (d) (ii) Deduce the engine speed, in revolutions per minute, at which the same effect would be likely to occur in the car.

....

....

(2 marks)